Losses in RFQ during Measurements with LEBT PBIs

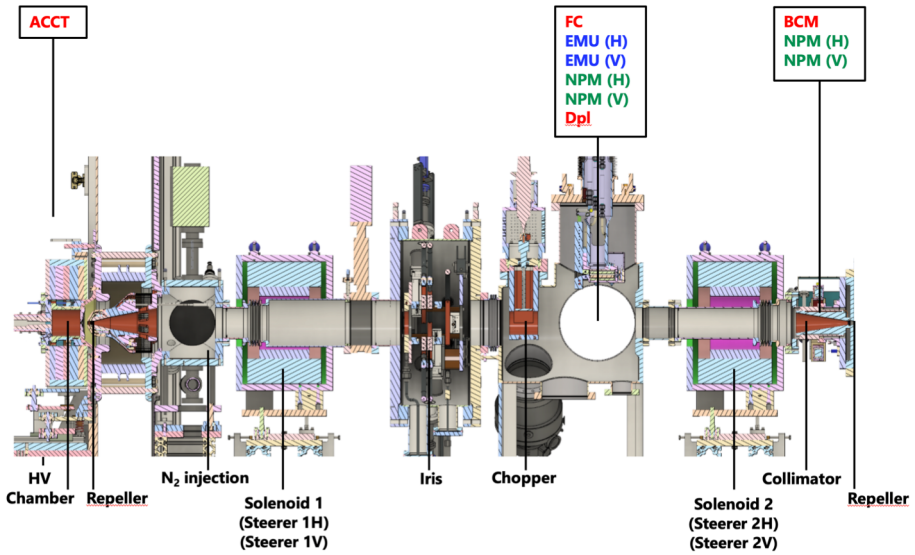
Ryoichi Miyamoto (AD/BP)

2020-12-02

BPOD Group Meeting

“Leak” current

- Insufficient LEBT chopper efficiency
  - Concerns:
    - Losses in RFQ
    - Excess charge deposition to the MEBT FC
  - To be studied
- Insufficient MEBT chopper efficiency
  - Concern:
    - Excess charge deposition to the MEBT FC
  - Estimating beam characteristics is trivial.
- Using EMU and NPM in LEBT with RFQ off
  - Concern:
    - Losses concentrated in the beginning of RFQ
  - **Today’s subject: Worse/better than the losses during operation?**
    - Cooling?
    - Long-term effect on the surface?
    - Instantaneous effect on the surface?



Losses in RFQ during the normal operations

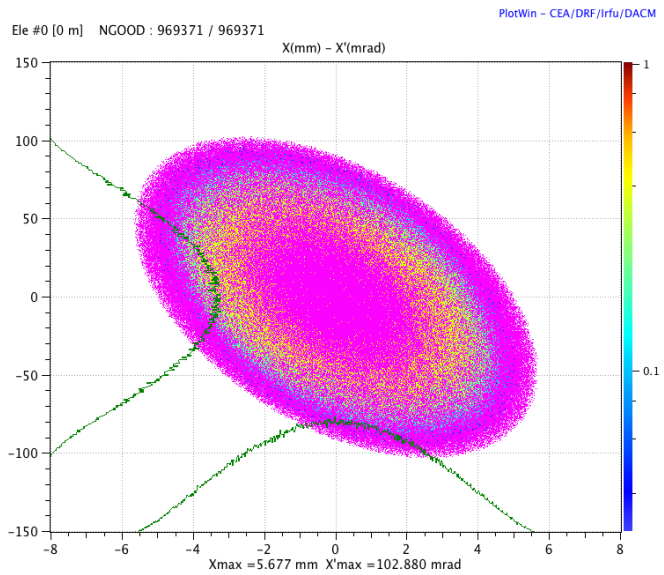
- Requirement on transmission is **90%** (ESS-0140709).
  - ~10% loss => **~70 mA injected** and **~7 mA lost**.
- 7 mA losses mean:
  - Cooling: **~21 W for 75 keV** and **~1 kW for 3.62 MeV**
  - Long-term effect: **~5000 C** loss per year (24 hours x 200 days)
  - Instantaneous effect: **~20 µC** loss per pulse
- How is the leak during usages of the EMU and NPM compared to those numbers?
  - We focus on the instantaneous case.

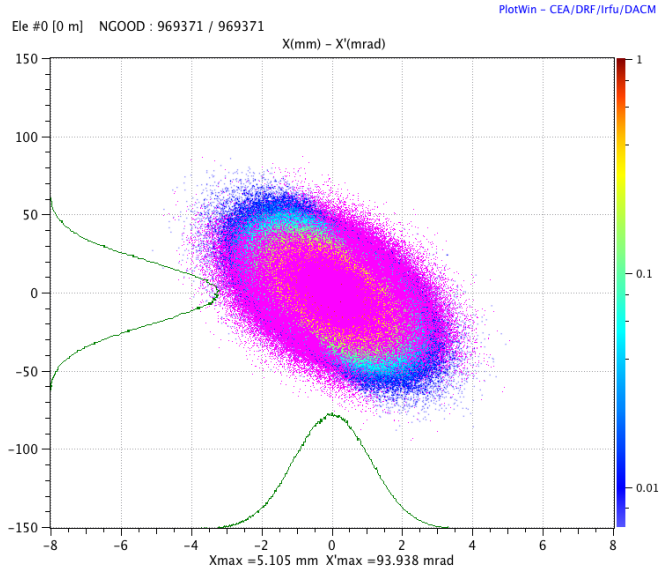
Loss pattern during the normal operations (1)
- Input distributions

0 mA Water-bag

$\varepsilon_{99.99\%}$ = 6.53

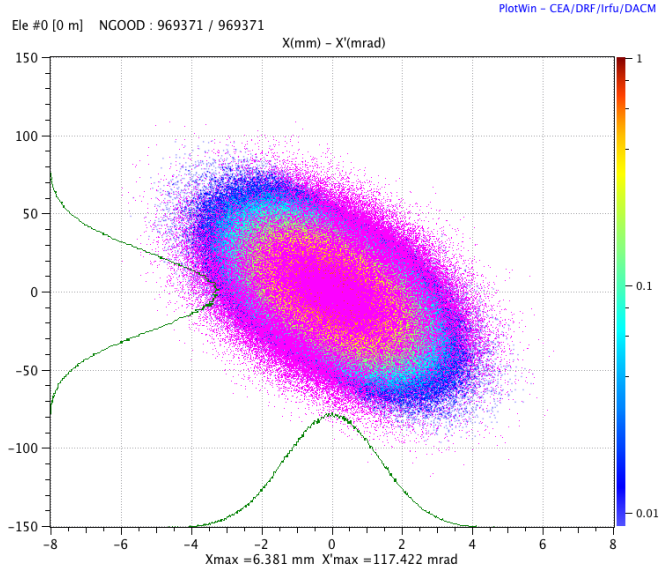
ε_{RMS} = 1.1





65 mA Gaussian

ε_{RMS} = 0.24

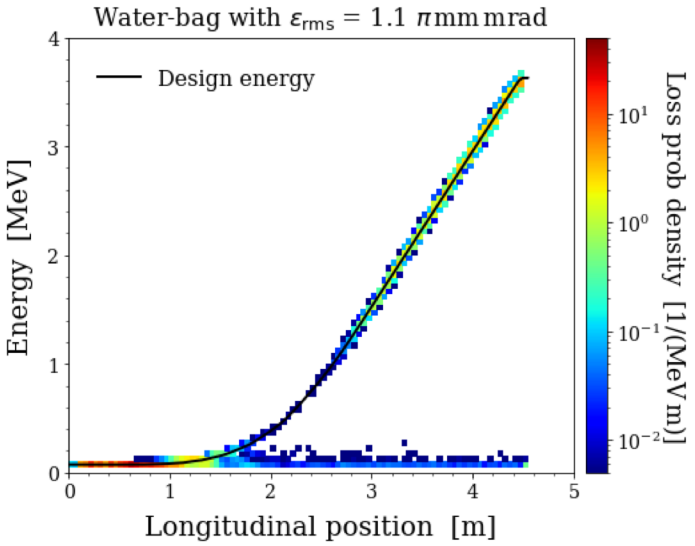


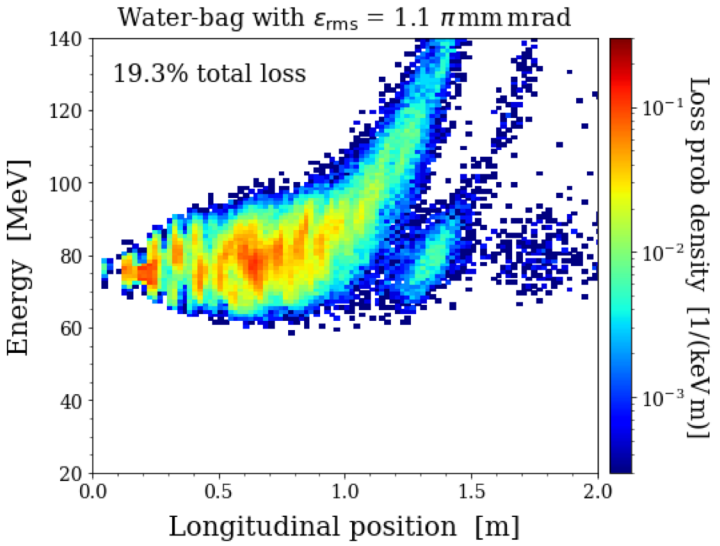
65 mA Gaussian

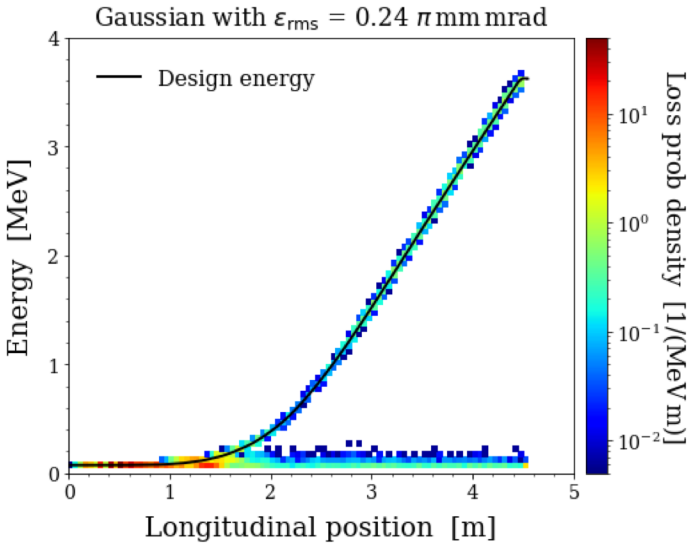
ε_{RMS} = 0.375

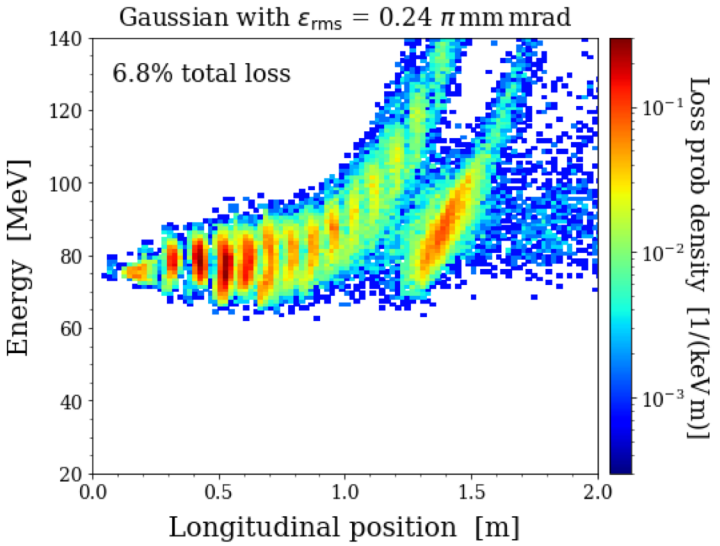
- Acceptance ($\varepsilon_{99.99\%}$) = 6.076 pi mm mrad
- β = 0.062 m
- α = 0.5175

Loss pattern during the normal operations (2)
- Lost particle energies

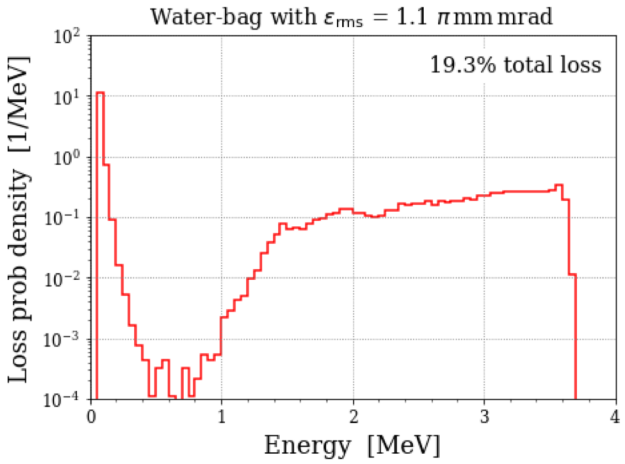


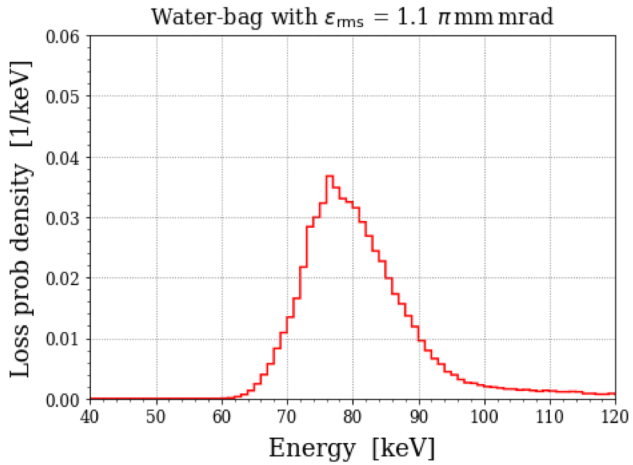


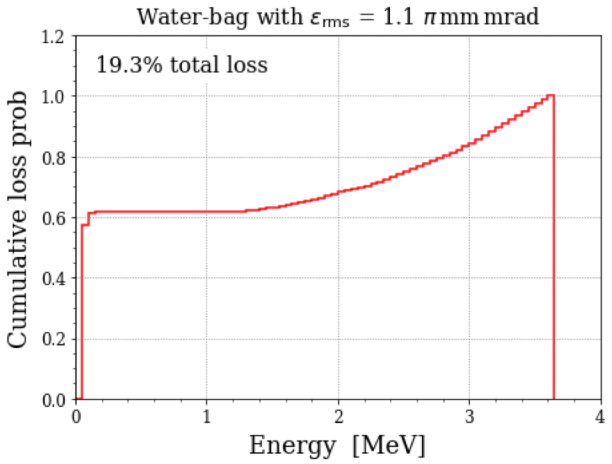


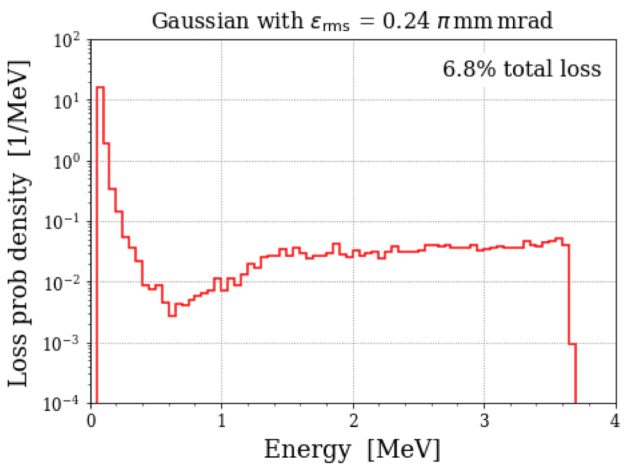


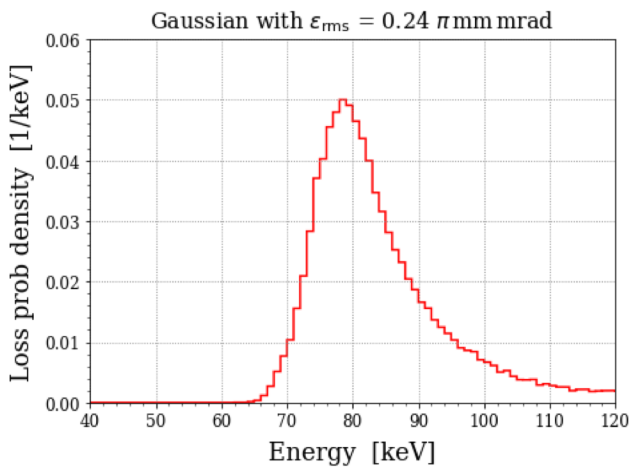
Loss pattern during the normal operations (3)
- Energy distribution

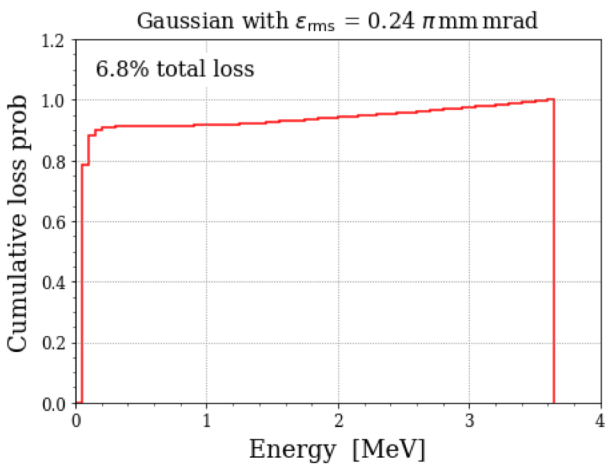






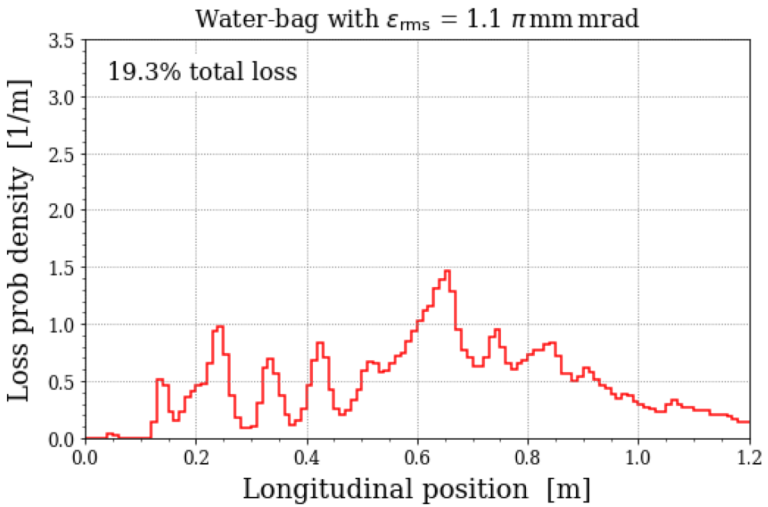


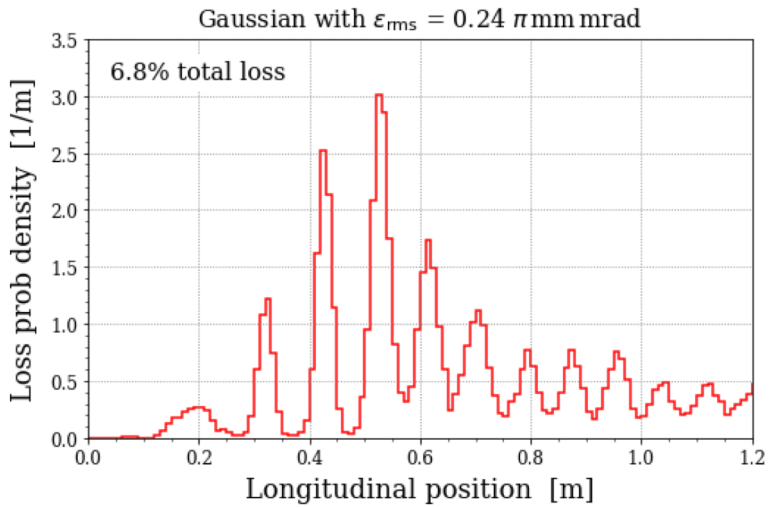




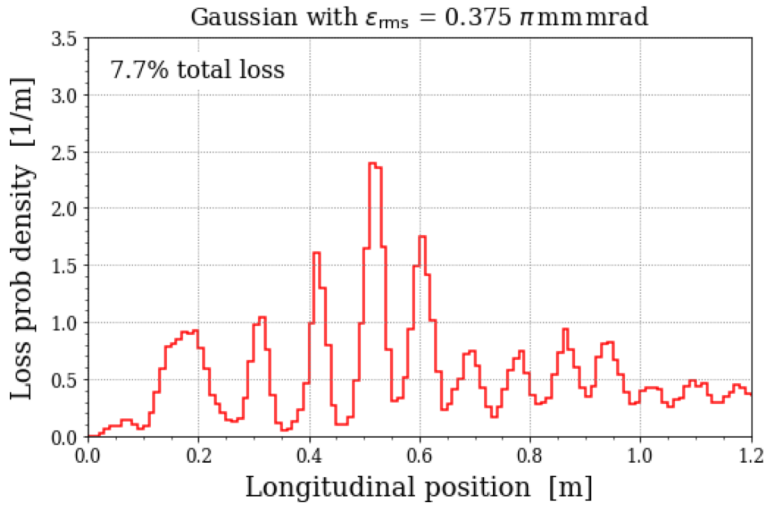
- Most losses could be around 80 keV.

Loss pattern during the normal operations (4)
- Longitudinal distribution near the entrance

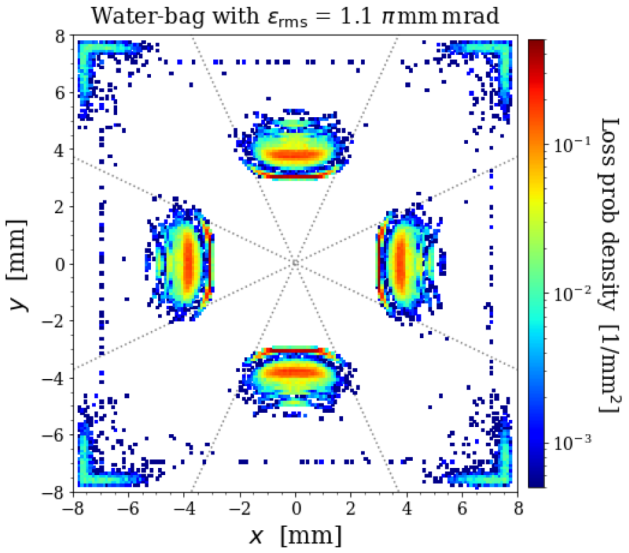


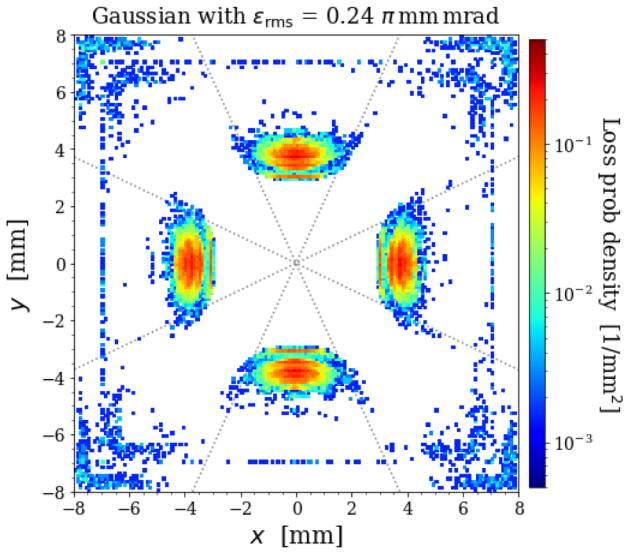


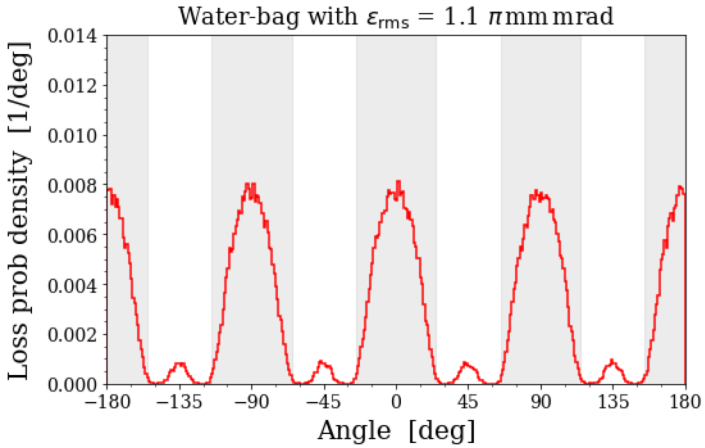
- The Gaussian cases with non-zero space-charge have peaks.
- A single peak for the Gaussian cases could include 10-15% of the total loss over ~5 cm
  - If 10% is lost, 1-1.5% of the whole beam.

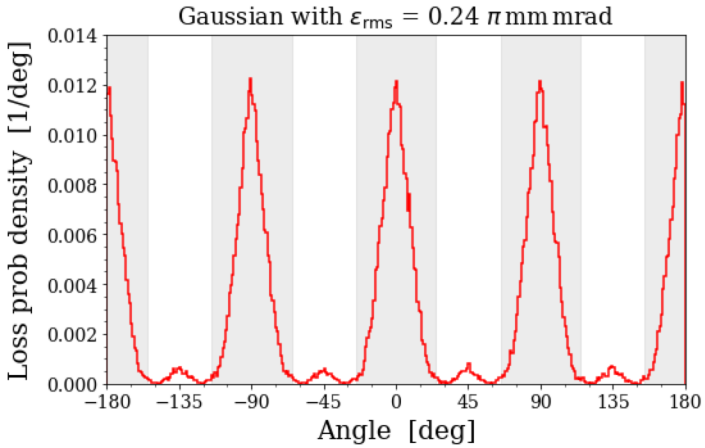


Loss pattern during the normal operations (5)
- Transverse distribution



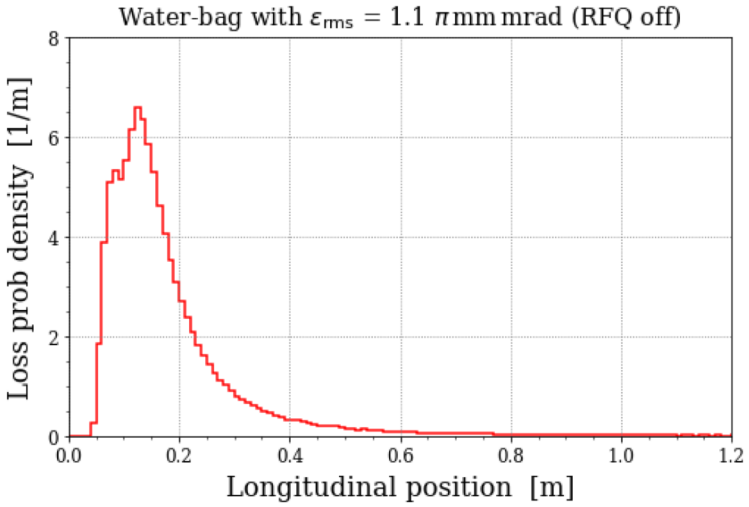


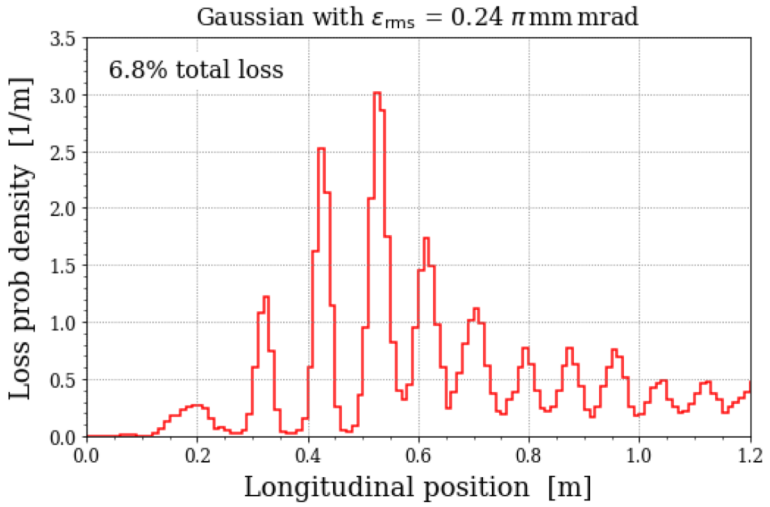


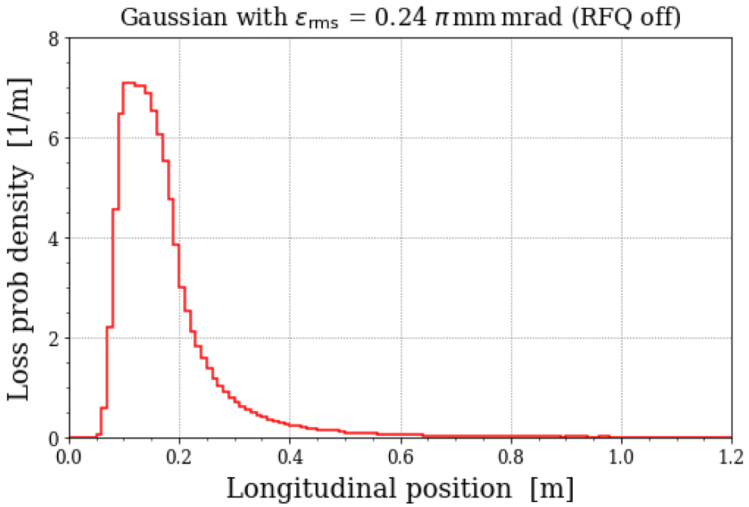


- Losses are concentrated on the vane tips.

Loss pattern when the RFQ is off (1)
- Longitudinal distribution

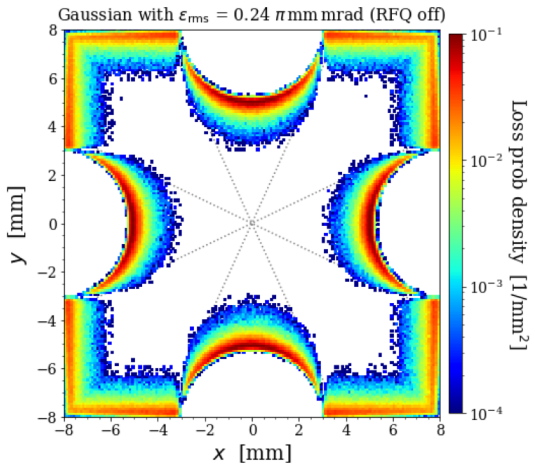


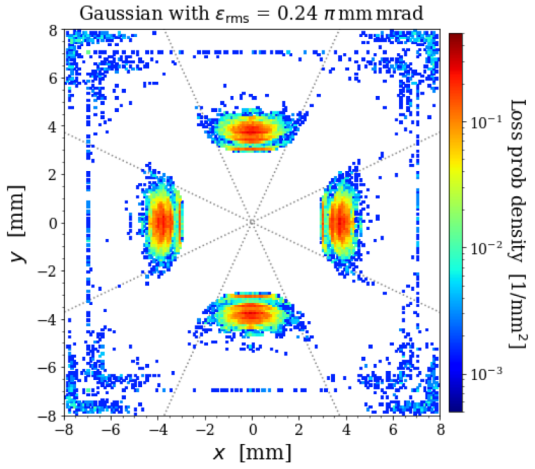


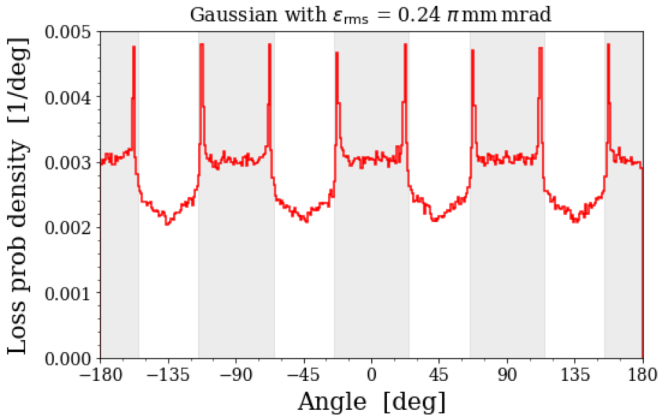


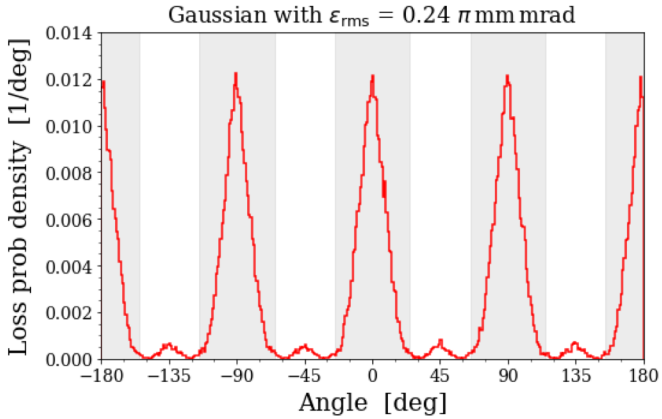
- Losses occur over ~15 cm.
- The peak density is larger by a few times than the case of the normal operations.

Loss pattern when the RFQ is off (2)
- Transverse distribution



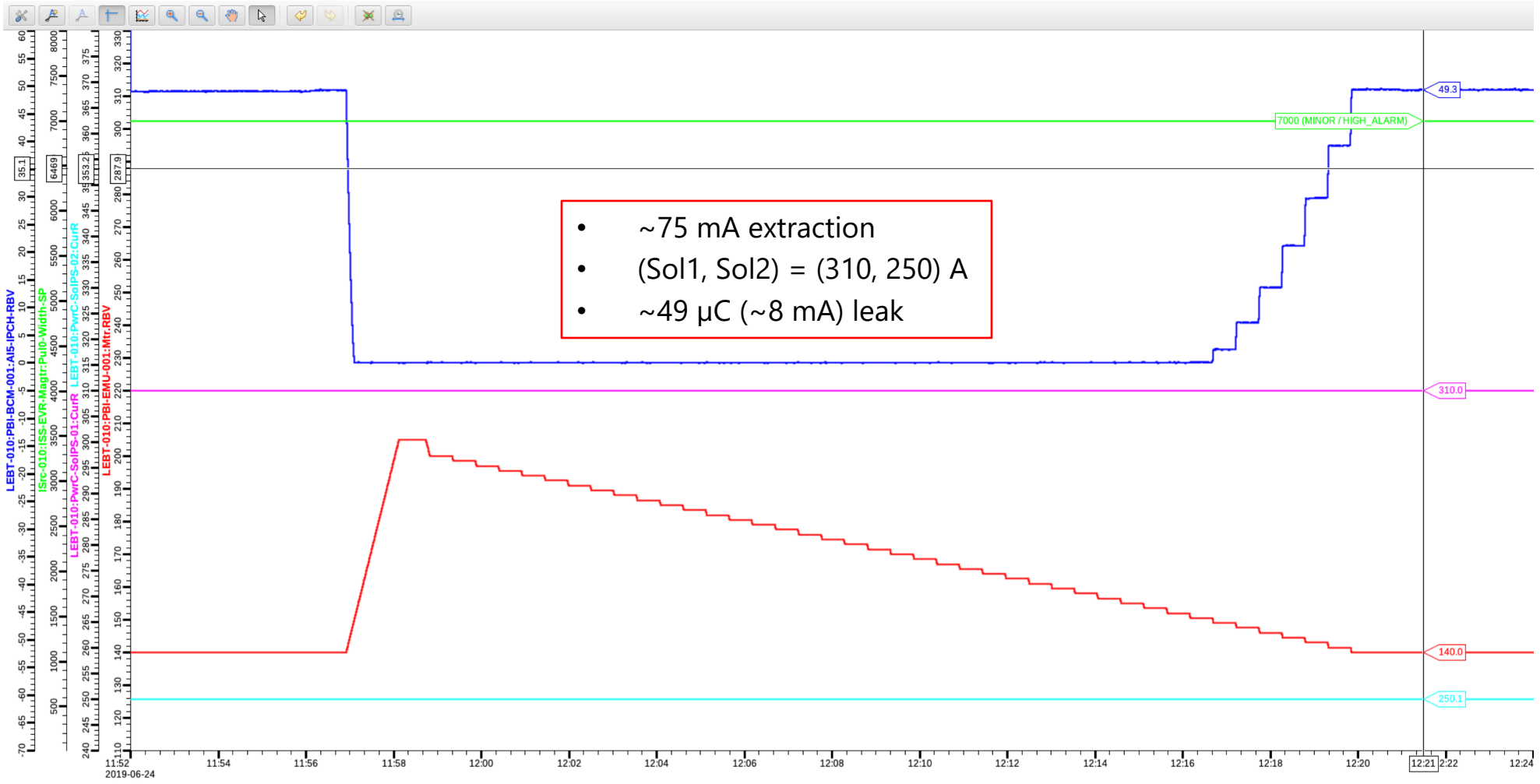






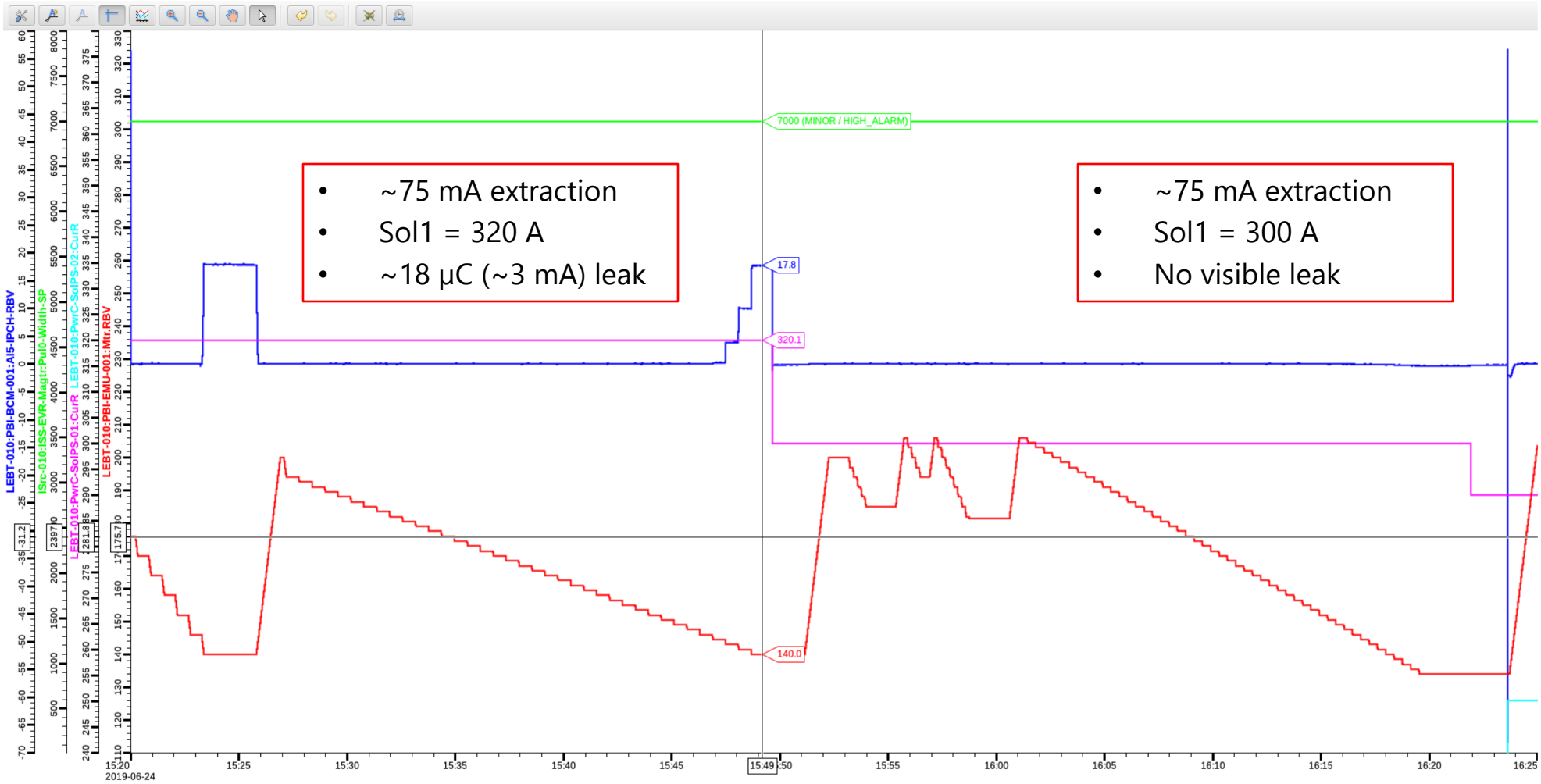
- The angular distribution is not far from the uniform.
- The peak density is smaller by a few times than the case of the normal operations.
  - **If the same amount of particles are lost, the energy deposition of ~75 keV particles over a unit surface is at the similar level with the RFQ on or off.**

What we saw during the beam commissioning (1) - EMU

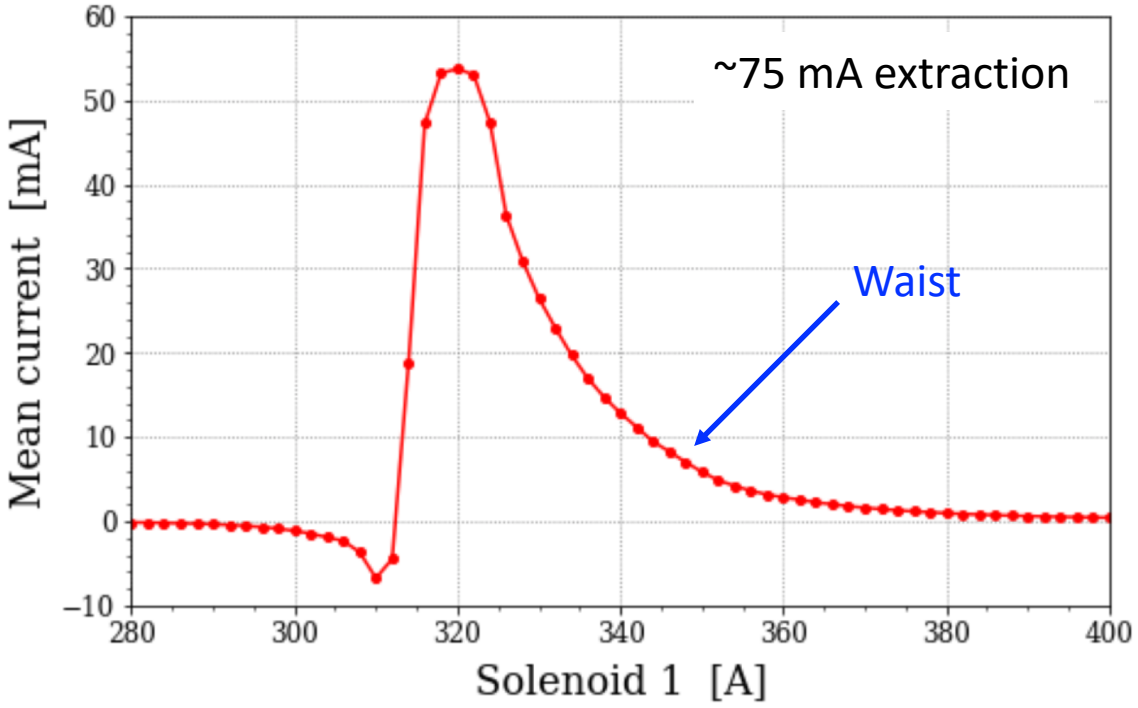


- ~75 mA extraction
- (Sol1, Sol2) = (310, 250) A
- ~49 µC (~8 mA) leak

What we saw during the beam commissioning (2) - EMU with Sol2 off



What we saw during the beam commissioning (3)
- Waist scan for NPM



- LEBT NPM needs a focused beam.
  - The standard way is to make the waist at the NPM.
  - For the beam steering, using the iris is good enough?
- The emittance reconstruction requires the waist scan.
- (Simulations of the loss pattern were already performed. To be analysed.)

Conclusions

- If the same amount of particles are lost with the RFQ on or off, the energy depositions from particles around 75 keV have a similar level of surface density.
  - Using the LEBT EMU shouldn't be a problem with Sol2 off, even without the LEBT chopper.
- Beam waist scan with Sol1 may require some restrictions:
  - Range in Sol1 and or applying chopping over a large part.
- We could nevertheless use thermomechanical simulations for some cases, especially for the 10% scenario during the normal operations.
- To-do: simulations for
  - Waist scan
  - (EMU)
  - LEBT chopper